INTERFERENCE MEASUREMENT AND EVALUATION SYSTEM

BACKGROUND OF THE INVENTION

1.   Field of the Invention

[0001]   The present invention relates to an interference measurement and evaluation system, more particularly relates to an interference measurement and evaluation system for estimating a receiving line quality characteristic due to nonlinear interference, reception thermal noise power, leakage power from an adjacent channel, etc. in a communication or broadcasting system using radio waves or optical communications.

2.   Description of the Related Art

[0002]   Wireless communication systems mainly suffer from mutual interference not only between terrestrial mobile wireless systems and terrestrial fixed wireless systems, but also between commercial wireless systems for space and mobile satellite communication systems. These mutual interferences include linear interference due to leakage power from adjacent or next-to-adjacent areas or linear interference due to frequency sharing and nonlinear interference where intermodulation distortion occurs due to high level interference power. In areas where the service areas are broad and many systems coexist, the study of nonlinear interference has been becoming important. These are also present in optical communications and broadcasting.

[0003]   For example, in areas with a coexistence of wireless systems such as conventional mobile wireless communication systems together or a mobile wireless communication system, terrestrial fixed microwave communication system, and mobile satellite communication system, the line quality has been evaluated by the leakage power of the linear parts of interference waves, filtering at the receiving side, the modulation/demodulation scheme, etc., but the nonlinear

- 2 -

interference has not been sufficiently evaluated.

[0004]   Further, while the performance relating to nonlinear interference in a receiver by themselves and individual specifications inside apparatuses of interfered wireless systems have been known, there has never been a means for estimating the above specifications as overall receiver performance in a transmitter and a receiver system.

[0005]   Nonlinear distortion has been analytically verified in the past. In this, using mathematical algorithms and introducing the third-order intercept point input level (IIP3) technique, the spread of an intermodulation product (IM) spectrum by a modulated wave, the occurrence of an interference wave due to IM, and the sensitivity suppression have been studied (for example, see "Study of Nonlinear Interference Theory Relating to Wide Band Mobile Wireless System and Narrow Band Mobile Wireless System", Journal of the EIAJ, EIAJ, RCS2002-140, August 22, 2002, and "Intercept Point and Undesired Responses", IEEE Transaction on Vehicular Technology, vol. VT32, no. 1, February 1983).

[0006]   Summarizing the problems to be solved by the invention, as explained above, in the past, sufficient nonlinear distortion was not taken against nonlinear interference, so there was the problem that it was not possible to analyze the cases of occurrence of nonlinear distortion due to nonlinearity of a receiver and power of the interfering wave, the frequency interval between the desired wave and interference wave, etc., so as to reduce the frequency of occurrence and deterioration of quality in the service area.

SUMMARY OF THE INVENTION

[0007]   An object of the present invention is to provide an interference measurement and evaluation means for accurately estimating an interference characteristic of a receiving side including nonlinear interference for a communication or broadcasting system using radio waves

- 3 -

or optical communication.

[0008]   Another object of the present invention is to provide an interference measurement and evaluation system enabling analysis of the frequency of occurrence of nonlinear interference for a wireless communication system.

[0009]   Still another object of the present invention is to provide an interference measurement and evaluation system using a nonlinear interference theoretical curve linked with a reception line quality characteristic for estimation of a reception characteristic under nonlinear interference, estimation of reception thermal noise power, estimation of the ratio between a third-order distortion coefficient a_3 and first-order coefficient a_1 due to nonlinear interference or third-order intermodulation (TTP3), or estimation of leakage power from an adjacent channel etc.

[0010]   To attain the above object, according to the present invention, there is provided an interference measurement and evaluation system comprised of a transmitting means for transmitting a digitally modulated wave signal, a receiving means for decoding a modulated signal from a modulated wave signal received from the transmitting means, and an interference characteristic estimating means for estimating an interference characteristic including a nonlinear interference characteristic by which the received modulated wave signal is affected from an interference signal for the received modulated wave signal due to the nonlinear characteristic of the receiving means, the interference characteristic estimating means referring to a level of the modulated wave signal received by the receiving means, a level of the interference signal, and a nonlinear interference theoretical curve given in relation to a line quality of a modulated signal decoded by the receiving means and estimating the interference characteristic including the nonlinear characteristic

- 4 -

possessed by the receiving means based on the measur d
level of the modulat d wave signal, level of the
interference signal, and line quality of the decoded
modulated signal.

[0011]   According to this interference characteristic
estimating means, the interference characteristics due to
a nonlinear interference wave of a receiving means in a
communication or broadcasting system using radio waves or
optical wave can be accurately quantized and estimated in
advance, so it is possible to accurately estimate
specifications from a nonlinear interference theoretical
curve as overall performance of reception even when the
performance of the reception system in a wireless
communication system relating to nonlinear interference
and the specifications inside an apparatus of the
interfered wireless system are unknown, therefore
possible to flexibly estimate the line quality for a
wireless communication system under nonlinear
interference envisioning a real environment and possible
to take measures to prevent deterioration of line
quality.

[0012]   These and other effects are considered the same
for an optical communication or broadcasting system etc.

[0013]   Preferably, the interference characteristic
measuring means estimates the nonlinear interference
characteristic possessed by the receiving means based on
the modulated wave signal of the region where the
nonlinear interference is dominant when the nonlinear
interference theoretical curve satisfies a predetermined
line quality and based on the received level of the
interference signal.

[0014]   Since it is possible to accurately estimate an
interference characteristic including nonlinear
interference possessed by the receiving means, it is
possible to prevent deterioration of the line quality in
wireless communication under nonlinear interference.

[0015]   More preferably, the receiving means is

- 5 -

provided with a receiving side interfered digital
wireless means receiving a composite signal of a
modulated wave signal from the transmitting means and an
interference signal from the nonlinear interfering means
and an error rate measuring means for measuring an error
rate in the composite signal, and the predetermined line
quality is a bit error rate free from an effect from a
received noise power, free from an effect of leakage
power, dominated by the nonlinear interference region,
and measured by the error rate measuring means.

[0016]   Since it is possible to accurately estimate the
bit error rate possessed by the receiving means, it is
possible to prevent deterioration of the bit error rate
in wireless communication under nonlinear interference
condition.

[0017]   More preferably, the transmitting means is
provided with a transmitting side variable attenuating
means for changing the transmitted signal level and the
nonlinear interference characteristic possessed by the
receiving means is estimated by changing the transmitted
signal level by the transmitting side variable
attenuating means.

[0018]   Due to this, the received signal level changes
in accordance with a change in the transmitted signal
level, the received level when the nonlinear interference
theoretical curve relating to the change satisfies a
predetermined line quality, and as a result the nonlinear
interference characteristic can be accurately estimated,
so the detrimental effect of nonlinear interference on
the receiving side can be accurately prevented.

[0019]   More preferably, the transmitting means and the
receiving means are provided between them with a
nonlinear interfering means having a carrier frequency
different from a frequency region of the transmitting
means and giving a nonlinear interference wave signal
having a non negligible level compared with the level of
the modulated carrier transmitt d from the transmitting

- 6 -

means, the transmitting means is provided with a
transmitting side variable attenuating means for changing
the interference signal level, and the nonlinear
interfering means is provided with an interfering side
variable attenuating means for changing the level of the
interference signal, and the transmitting side variable
attenuating means and the interfering side variable
attenuating means are adjusted to make the ratio of the
transmitting signal level and the level of the
interference signal constant and give it to the receiving
side interfered digital wireless means, whereby the
nonlinear characteristic possessed by the receiving means
is estimated.

[0020]   Since the received level is estimated when the
nonlinear interference theoretical curve, that relates to
a change in the received signal level when the ratio
between the transmitted signal level and the level of the
interference signal is constant, satisfies a
predetermined line quality. As a result, the nonlinear
interference can be accurately estimated, and the
detrimental effect of nonlinear interference on the
receiving side can be accurately prevented.

[0021]   More preferably, the receiving means is
provided with a receiving side variable attenuator for
changing an input signal level from the transmitting
means and changes the input signal level so as to
estimate the nonlinear interference characteristic
possessed by the receiving means.

[0022]   Due to this, it is possible to estimate the
nonlinear interference characteristic at any received
signal level.

[0023]   Still more preferably, the interference
characteristic estimating means estimates a thermal noise
power based on the nonlinear characteristic given to the
receiving means based on the received signal level of the
region where the received thermal noise power is dominant
when the nonlinear interference theoretical curve

- 7 -

satisfies a pred termined line quality.

[0024]   Since the thermal noise pow r based on the nonlinear characteristic given to the receiving means can be accurately estimated, the minimum received level given by the thermal noise on the receiving side is accurately determined without nonlinear interference.

[0025]   More preferably, the nonlinear interfering means is provided with a frequency converting means for converting a center frequency of a nonlinear interference wave, and the interference characteristic estimating means estimates a received equivalent band limitation characteristic possessed by the receiving means when converting the center frequency of the nonlinear interference wave by the frequency converting means.

[0026]   Since the received equivalent band limitation characteristic possessed by the receiving means can be estimated, it becomes possible to suitably set the band limitation characteristic of the receiving means.

[0027]   Still more preferably, the interference characteristic estimating means estimates a leakage power of the receiving means based on a received signal level of a region where a leakage power is dominant when the nonlinear interference theoretical curve satisfies a best line quality.

[0028]   Since it is possible to estimate the leakage power of the receiving means under nonlinear interference, measures can be taken to reduce the leakage power.

[0029]   Still more preferably, the interference characteristic measuring means is provided with a frequency converting means for converting a center frequency of an interference signal, and the interference characteristic estimating means finds a receiving side input level giving the best line quality characteristic and its line quality based on a receiving side input level receiving line quality characteristic of the modulated wave signal for an offset frequency of the

- 8 -

interference signal when converting the center frequency
of the int rferenc signal by the frequency converting
means and the nonlinear interference theoretical curve
and estimating the received equivalent leakage power for
the offset frequency of the receiving side as a whole
using this.

[0030]   Since it is possible to estimate the leakage
power of the receiving means even when the frequency of
the interference signal changes, measures can be taken to
reduce the leakage power.

[0031]   Still more preferably, when measured values of
a receiving side input level and a received line quality
characteristic linked with the nonlinear interference
theoretical curve are discrete, the means finds by
approximation the receiving side input level giving the
best line quality characteristic and that received line
quality and estimates the received equivalent leakage
power with respect to the offset frequency of the
receiving means by this

[0032]   Since it is possible to estimate the leakage
power of the receiving means in accordance with a change
in the center frequency of the interference signal even
if the measured values are discrete, measures can be
taken to reduce the leakage power.

[0033]   More preferably, the interference
characteristic estimating means estimates the line
quality characteristic of the receiving means with
respect to an interference signal including a nonlinear
interference wave of any frequency and of any level based
on the nonlinear interference theoretical curve, a
thermal noise power estimated given to the receiving
means based on a received signal level of a region where
the received thermal noise power is dominant when the
nonlinear interference theoretical curve satisfies a
predetermined line quality, and the equivalent leakage
power.

[0034]   Since it is possible to estimate the line

- 9 -

quality characteristic of the receiving means for an interference signal of any frequency and of any level, it is possible to take measures to prevent deterioration of the line quality of the receiving means due to an interference signal.

[0035]   Preferably, the interference characteristic estimating means estimates by approximation an interference characteristic including a nonlinear interference characteristic possessed by the receiving means based on a line quality of a decoded signal of a discrete receiving side input level versus modulated wave signal characteristic of a modulated wave signal measured over a range near the modulated wave signal from a state where there is no signal giving nonlinear interference to the receiving means to a state giving nonlinear interference.

[0036]   Since the interference characteristic including a nonlinear interference characteristic possessed by the receiving means is estimated by approximation based on the discrete measured values of the received level of the receiving means and the line quality even if there is no signal giving nonlinear interference to the receiving means, the limitation on the frequency of the interference signal is eased and estimation of the interference characteristic becomes easy.

[0037]   Preferably, the interference characteristic estimating means estimates the nonlinear interference of the receiving means based on a region where an adjacent power dominates and a received level of a region where the received thermal noise dominates in the nonlinear interference theoretical curve.

[0038]   Since it is possible to estimate a nonlinear interference characteristic of the receiving means even without measuring the received level at a region where the interference power is dominant, estimation of the nonlinear interference characteristic becomes easy.

[0039]   More preferably, the interference

- 10 -

characteristic estimating means estimates the nonlinear interference characteristic of the receiving means based on the nonlinear interference theoretical curve and the estimated thermal noise power even when the modulated wave signal and the interference signal approach each other in frequency to an extent where the adjacent power increases.

[0040]   Since it is possible to estimate the nonlinear interference characteristic of the receiving means even when the modulated wave signal and the interference signal are close in frequency, estimation of the nonlinear interference characteristic becomes easy.

[0041]   Summarizing the above, in the present invention, the nonlinear interference is expressed as the nonlinear characteristic of the interfered reception system by a_3/a_1 or the intercept point input level (IIP), the third-order distortion of the receiving characteristic is linked with the bit error rate (BER) as one example of the line quality from the interference leakage power from a_3/a_1 or the intercept point input level IIP3 and the reception system thermal noise, estimation of the a_3/a_1 or the intercept point input level IIP3 of reception as a whole, which was difficult to quantize in the past, is made possible, provision is made of a means for more accurately providing the line quality under nonlinear interference from the estimated a_3/a_1 or IIP3, and a good line quality is made possible.

[0042]   The above explanation was mainly made regarding a wireless communication system, but the invention can also clearly be similarly applied to a communication system or broadcasting system using light.

    BRIEF DESCRIPTION OF THE DRAWINGS

[0043]   These and other objects and features of the present invention will become clearer from the following description of the preferred embodiments given with reference to the attached drawings, wherein:

    FIG. 1 is a block diagram of the configuration of an

- 11 -

interference measurement and evaluation system according
to a first embodiment of the present invention,

FIG. 2A is a view of an example of a spectrum of an
input signal (modulated wave signal) input to a receiving
means, while FIG. 2B is a view of the spectrum of an
output signal output from the receiving means in response
to the input signal shown in FIG. 2A,

FIG. 3 is a graph for explaining the levels of a
main signal, third-order distortion signal, and fifth-
order distortion signal when the receiving side receives
as input two signals of the same level close in
frequency,

FIG. 4 is a graph for estimating an intercept point
from the relationship between an input level and output
level at the receiving side,

FIG. 5A is a view of an example of the spectrum of
an input signal (modulated wave signal) input to a
receiving means, while FIG. 5B is a view of the spectrum
of an output signal for explaining an increase in
adjacent leakage power due to an interference wave
intermodulation product output from a receiving means in
response to the input signal shown in FIG. 5A,

FIG. 6 is a graph of an example of a bit error rate
characteristic as an example of a line quality
characteristic under nonlinear interference measured by
using the interference measurement and evaluation system
shown in FIG. 1 as a test system,

FIG. 7 is a block diagram of the configuration of an
interference measurement and evaluation system according
to a second embodiment of the present invention,

FIG. 8 is a graph of an example of the bit error
rate characteristic under nonlinear interference measured
by using the test system shown in FIG. 7,

FIG. 9 is a view of a thermal noise characteristic
under nonlinear interference measured by using an
interference wave power as a parameter,

FIG. 10 is a view of a thermal noise characteristic

- 12 -

under nonlinear interference measured by using an interference wave power as a parameter,

FIG. 11 is a block diagram of the configuration of an interference measurement and evaluation system according to a third embodiment of the present invention,

FIG. 12 is a graph of an example of estimation of an equivalent attenuation of power of a receiving side when changing the frequency interval of an interference signal and interfered wave under nonlinear interference measured by using the interference measurement and evaluation system shown in FIG. 11,

FIG. 13 is a graph of an example of estimation of an equivalent leakage power of a receiving side under nonlinear interference measured by using an interference measurement and evaluation system shown in FIG. 1,

FIG. 14 is a graph of the bit error rate characteristic under nonlinear interference measured by using the test system shown in FIG. 7, and

FIG. 15 is a graph of the bit error rate characteristic under nonlinear interference in a 10th embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0044]   Preferred embodiments of the present invention will be described in detail below while referring to the attached figures. Note that in the following explanation, the same reference numerals indicate the same elements.

First Embodiment

[0045]   FIG. 1 is a block diagram of the configuration of an interference measurement and evaluation system according to a first embodiment of the present invention. In the figure, 11 is an error rate measuring equipment (transmitting side), 12 is an interfered digital wireless equipment (transmitting side), 13 is a variable attenuator for controlling the transmission output level of the interfered digital wireless equipment 12, 14 is a signal generator for generating a modulated signal of an interfered digital wireless equipment, 15 is an

- 13 -

interfered digital wireless equipment (transmitting side), 16 is a variable attenuator for controlling the transmission output level of an interfered digital wireless equipment, 17 is a hybrid composition circuit for combining a modulated wave signal output which is output from the interfered digital wireless equipment 12 and passes through the variable attenuator 3 and a modulated wave signal output which is output from the interfered digital wireless equipment 15 and passes through the variable attenuator 16, 18 is an interfered digital wireless equipment (receiving side), 19 is an error rate measuring equipment (receiving side), and 20 is an interference characteristic estimating means including a nonlinear interference characteristic provided according to an embodiment of the present invention.

[0046]   The error rate measuring equipment 11, interfered digital wireless equipment 12, and variable attenuator 13 constitute a transmitting means 101. The interfered digital wireless equipment 18 and the error rate measuring equipment 19 constitute a receiving means 102. The interfered modulated signal generator 14, interfered digital wireless equipment 15, variable attenuator 16, and hybrid composition circuit 17 constitute a nonlinear interfering means 103.

[0047]   The interference characteristic estimating means 20 may be realized by any control device such as a microprocessor.

[0048]   In the present embodiment, the interference measurement and evaluation system is configured as an error rate characteristic test system having a variable attenuator 13 (transmitting side variable attenuating means) for making the power of the interference wave constant and changing the input level of a modulated wave signal given to the receiving side to the receiving means 102 and measuring the error rate of a wireless communication line under interference. The interference

- 14 -

characteristic estimating means 20 utilizes a nonlinear
interference theoretical curve known in advance,
establishes correspondence of the receiving side input
level of a modulated wave signal and reception bit error
rate as an example of line quality as measured values
with the above nonlinear interference theoretical curve,
and estimates a nonlinear interterence characteristic of
the receiving side.

[0049]   Note that the line quality characteristic is
not limited to the bit error rate and may also be a frame
error rate, block error rate, packet error rate, etc.

[0050]   FIG. 2A is a view of an example of a spectrum
of an input signal (modulated wave signal and
interference signal) input to a receiving means 102,
while FIG. 2B is a view of the spectrum of an output
signal output from the receiving means 102 in response to
the input signal shown in FIG. 2A. In the illustrated
example, for simplification of the explanation, the
frequency of the interfered wave signal in the input
signal is the unmodulated f_{c1}, and the interference
signal is a modulated continuous spectrum having f_{c2} as a
center frequency and having a $2f_{m1}$ bandwidth, but the
interfered wave signal and the interference signal may
also be an unmodulated frequency or have a modulated
continuous frequency band.

[0051]   The output signal spectrum, as shown in FIG.
2B, shows the occurrence of an interference wave having a
bandwidth of $\pm 2f_{m1}$ about the basic frequency f_{c1} of the
interference wave and the occurrence of an interference
wave having a bandwidth of $\pm 2f_{m1}$ about the frequency f_{c1}
of the side band wave of the interference wave. FIG. 2D
shows the interference bandwidth $\pm 3f_{m1}$ due to the
interfered wave signal centered about the center
frequency f_{c4} of the interference signal.

[0052]   The ratio D/U between the output level D
(desired) of the basic frequency of an output signal at
the basic frequency and an output level U (Undesired)

- 15 -

expresses the degree of interference distortion. The
smaller the D/U ratio, the larger the interference
distortion. The present invention provides an
interference evaluation system for estimating the
nonlinear interference at this D/U ratio.

[0053]   FIG. 3 is a graph for explaining the levels of
a main signal, a third-order distortion signal, and a
fifth order distortion signal in the case of receiving as
input at a receiving side two signals of the same level
with close frequencies. In FIG. 3, when the two basic
signals (P_t) of the close frequencies f_{a1} and f_{a2} are
input, third-order distortion of a level P_{IM3} is caused by
frequencies of $2f_{a2}-f_{a1}$ and $2f_{a1}-f_{a2}$ and fifth-order
distortion of a level P_{IM5} is caused by frequencies of
$3f_{a2}-2f_{a1}$ and $3f_{a1}-2f_{a2}$.

[0054]   FIG. 4 is a graph for estimating an intercept
point from a relationship of the input level and output
level at a receiving side. In FIG. 4, the line "a" shows
the relationship between the input levels and output
levels of the two basic signals, the line "b" shows the
relationship between of the output level of the third-
order distortion IM (intermodulation) with respect to the
input level of the basic signal, and the line "c" shows
the relationship of the output level of the fifth-order
distortion IM (intermodulation) with respect to the input
level of the basic signal. If the levels of the two basic
signals are simultaneously raised, the difference IM_3
(see FIG. 3) between the level P_t of the basic signal and
the level P_{IM3} of the third-order distortion signal will
gradually become smaller. The output of the receiving
side in an actual wireless communication system becomes
saturated as shown by the solid line in the figure, but
if assuming that the output level increases linearly in
proportion to the input level, the line "b" showing the
third-order distortion will intersect with the part shown
by th broken line of the basic signal. The output level
at the intersection point is called the "third-order

- 16 -

intercept point output level", while the input level is
called the "third-order intercept point input level". The
present invention estimates this third-order intercept
output level or third-order intercept input level by the
interference characteristic estimating means 20.

[0055]   This estimating technique will be explained
below.

[0056]   If expressing the baseband of an interference
signal of an interfering means 103 (hereinafter called
the "interfering side") by $g(t)$, designating the in-phase
component by $I(t)$, designating the orthogonal component
by $Q(t)$, and designating the carrier of the mobile
wireless equipment of the transmitting means 101
(hereinafter called the "interfered side") the
unmodulated wave of the frequency f_{c1} as shown in FIG. 2,
the input signal to the receiving means 102 (receiving
side) is expressed by equation (1):

$$x(t)=V_1 \cdot \cos(2\pi f_{c1}t)+I(t)\times\cos(2\pi f_{c2}t)+Q(t)\times\sin(2\pi f_{c2}t) \quad (1)$$

where,

V_1: carrier voltage of mobile wireless equipment of
interfered side

f_{c1}: carrier frequency of mobile wireless equipment
of interfered side

$I(t)$: modulated signal voltage of in-phase component
of baseband of mobile wireless equipment of interfering
side

$Q(t)$: modulated signal voltage of orthogonal
component of baseband of mobile wireless equipment of
interfering side

f_{c2}: carrier frequency of mobile wireless equipment
of interfering side

[0057]   Further, if setting $g(t) = \{I(t)^2+Q(t)^2\}^{1/2}$ and
$\theta(t) = \arctan\{Q(t)/I(t)\}$, this is converted to the
following equation (2):

$$x(t)=V_1 \cdot \cos(2\pi f_{c1}t)+g(t)\times\cos(2\pi f_{c2}t+\theta(t)) \quad (2)$$

Here,

- 17 -

g(t): modulated signal composite voltage of baseband
of mobile wireless equipment of interfering side

θ(t): phase of carrier frequency of mobile wireless
equipment of interfering side

[0058]   Further, if expressing g(t) by the spectrum
component, this becomes the following equation (3):

$$g(t) = \Sigma V_2(k) \times \cos(k \cdot 2\pi \Delta f_m \cdot t + \Delta\theta_k) \tag{3}$$

[1≤k≤n]

Here,

$V_2(k)$: k-th modulated signal voltage of baseband of
mobile wireless equipment of interfering side

Δf_m: modulated frequency interval of baseband of
interfering side

$\Delta\theta_k$: phase of modulated frequency of mobile wireless
equipment of interfering side

$Fm = n \times \Delta f_m$: maximum modulated frequency of mobile
wireless equipment of interfering side

[0059]   If expressing the input signal at the receiving
side amplifier as x(t) and the output signal as y(t) and
expressing the nonlinear characteristic by power series
expansion, the following equation (4) is obtained:

$$y(t) = a_1 x(t) + a_2 x(t)^2 - a_3 x(t)^3 \tag{4}$$

[0060]   Here, a_1, a_2, a_3... are coefficients of power
series expansion, and the sign of the third-order
coefficient a_3 is made a minus sign from the saturation
characteristic of the amplifier.

[0061]   When $f_{c2} - f_{c1} > 3f_m$ by the frequency array shown in
FIG. 2, the nonlinear interference of a narrow band
mobile wireless equipment expressed by the unmodulated
wave (frequency f_{c1}) is expressed by the sensitivity
suppression of the output signal of the receiving side of
the frequency f_{c1}, the power ratio (C/I_3) of the power C
of the frequency f_{c1} at the output signal of the
receiving side and the power I_3 of the third-order
nonlinear intermodulation component (maximum modulation

- 18 -

frequency $2f_m$) of the modulated signal of the broad band mobile wireless equipment relating to the frequency f_{c1}, etc. Therefore, the sensitivity suppression and the power ratio are estimated as follows:

(1) Estimation of Sensitivity Suppression of input Signal of Receiving Side

[0062]   If expressing the sensitivity suppression η due to nonlinear interference in dB and entering equation (2) into equation (4), the unmodulated wave (frequency f_{c1}) component y_{tc1} is expressed by the following equation (5):

$$y_{tc1} = a_1 V_1 \cdot \cos(2\pi f_{c1} t) - a_3 V_1{}^3/2 \cdot \cos(2\pi f_{c1} t) - a_3 V_1 \cdot 3/2 \cdot \cos(2\pi f_{c1} t) \times g(t)^2 \quad (5)$$

[0063]   If designating the power of the interfering wave side as P_2, P_2 is expressed by the following equation (6):

$$P_2 = \int_0^T g(t)^2 \times \cos^2(2\pi f_{c1} t) / (T \cdot R) \, dt \quad (6)$$

where, T is the integrated time interval, $g(t)$ is expressed by equation (3), and, when $V_2 = V_2(k)$, $P_2 = 1/2 \cdot V_2{}^2/2/R$.

[0064]   Here, R is the input impedance of the receiving side.

[0065]   The relationship between the ratio a_3/a_1 of the coefficients a_3 and a_1 in equation (4) and the input third-order intercept point IIP3 is known in advance and may be expressed as follows:

$$a_3/a_1 = 1/(3/2 \cdot R \cdot IIP3)$$

[0066]   If designating the input impedance of the receiving side as R and normalizing the input powers V_1 and V_2 of the receiving side of the frequencies f_{c1} and f_{c2} by the input third-order intercept point IIP3, the powers I_{i1} and I_{i2} become as follows:

$$I_{i1} = V_1{}^2/2/R/(IIP3)$$
$$I_{i2} = 1/2 \cdot V_2{}^2/2/R/(IIP3)$$

[0067]   The sensitivity suppression is expressed by the

- 19 -

following equation (7):

$$\eta-20\times\log|1-I_{I11}-2\cdot I_{i2}| \tag{7}$$

[0068]   The sensitivity suppression η at the input signal of the receiving side for finding the nonlinear interference can be estimated based on the third-order input intercept point IIP3 found from the received power (received signal level) and nonlinear interference theoretical curve.

[0069]   In place of the IIP3, it is also possible to use the third-order output intercept point OIP3. Further, if it is possible to find the coefficient ratio a_3/a_1 by another technique, that may be used as well.

    (2)   Estimation of Power Ratio (C/I_3) Between Power C of Carrier f_{c1} at Output Signal of Receiving Side and Power of Nonlinear Third-Order Interference Wave Relating to That Carrier f_{c1}

[0070]   The double modulated wave component of the f_{c1} component of the output signal of the receiving side is expressed by the following equation (8) from the third term of equation (5):

$$y_{c1-m}=-a_3V_1\cdot3/2\cdot\cos(2\pi f_{c1}t)\times g(t)^2 \tag{8}$$

[0071]   If using the value T_{i2} obtained by normalizing the total power of the frequency f_{c2} by the input third-order intercept point IIP3, the power ratio (C/I_3) of the power C of the carrier f_{c1} at the output signal of the receiving side and the third-order power related to this carrier f_{c1} becomes the following equation (9):

$$C/I_3=-10\log(Iin^2)+A \tag{9}$$

[0072]   Here, A is a constant determined by the frequency spectrum distribution of the interference wave frequency f_{c2}, maximum modulation frequency, and equivalent reception band width (BW) of the frequency f_{c1}.

[0073]   When the frequency spectrum distribution of the interference frequency f_{c2} is constant, if entering equation (3) for g(t) in equation (8) and finding the

- 20 -

power, the power spectrum component (P_{c1-m}) of the interference wave output from the receiving side becomes the following equations (10) to (12):

$$P_{c1-m} = (-a_3 3/2)^2 \cdot (P_{c1}) \cdot (2R \cdot Pin/Fm)^2 \times |f_m|/2) \tag{10}$$

$$-Fm \leq f_m < 0 \,|\, 0 \leq f_m \leq Fm$$

$$+ (-a_3 3/2)^2 \cdot (P_{c1}) \cdot (2R \cdot Pin/F_m)^2 \times (Fm - |f_m|/2) \tag{11}$$

$$2Fm \leq f_m <\ Fm \,|\, Fm < f_m \leq 2Fm$$

$$+ (-a_3 3/2)^2 \times (P_{c1}) \times (2R \times Pin/Fm)^2 \times (Fm - |f_m|) \tag{12}$$

$$-F_m \leq f_m < 0 \,|\, 0 \leq f_m \leq Fm$$

[0074]   If making the reception pass band BW of the interfered wave frequency f_{c1} much less than Fm, from the power spectrum P_{c1-m} expressed by equations (10) to (12), the power (P_{BW}) of the interference wave in the range of $f_{c1}-BW/2 < fm < f_{c1}+BW/2$ is obtained by integrating equation (10) to equation (12).

[0075]   Normalizing the powers of the frequencies f_{c1} and f_{c2} by the input third-order intercept point IIP3 and applying

$$a_3/a_1 = 1/(3/2 \cdot R \cdot IIP3)$$

$$I_{x1} = V_1^2/2/R/(IIP3)$$

$$I_{x2} = 1/2 \cdot V_2^2/2/R/(IIP3)$$

to P_{BW}, the power I_3 of the interference wave output from the receiving side is estimated by the following equation (13):

$$I_3 = 2(-a_1/IIP3)^2 \cdot (P_{c1}) \cdot (2 \cdot Pin/Fm)^2 \times (Fm \times BW/2 - BW^2/16)$$

$$\tag{13}$$

[0076]   The ratio (C/I_3) of the power C, where C = $(a_1 \times V_1)^2/3/R)$, of the basic component of f_{c1} with I_3 expressed by equation (13) becomes:

$$C/I_3 = -10 \times log[8 \times Iin^2 \times (BW/Fm/2 - (BW/Fm)^2/16)] \tag{14}$$

[0077]   The constant A of equation (9) is

$$A = 10 \times log[8 \times (BW/Fm/2 - (BW/Fm)^2/16)] \tag{15}$$

- 21 -

(3)   Estimation of Error Rate Characteristic

a)   QPSK Delay Detection Type Simplified Error Rate Characteristic is:

$$BER=1/2 \times \exp(-\rho/2) \tag{16}$$

[0078]   Here, if the signal to noise power ratio is ρ,

$$\rho = A^2/2/50/\sigma^2 \tag{17}$$

where, σ^2: noise power, A: amplitude of carrier, 50: impedance

[0079]   If the reception power of the frequency f_{c1} is C and the sensitivity suppression is η, ρ becomes the following equation (18):

$$\rho = 1/\{1/(\eta \cdot \delta \cdot C/P_N) + 1/(\eta \cdot \delta \cdot C/I_{ACP}) + 1/(\eta \cdot \delta \cdot C/I_3)\} \tag{18}$$

where,

I_{ACP}: leakage power affecting interfered wireless communication as calculated from interference wave power and reduction factor (IRF) ($I_{ACP} = IRF \times power\ P_s$ of interference wave side)

[0080] C/I_3 is the power ratio (truth value) of the f_{c1} component expressed by equation (15) and the intermodulation wave component relating to f_{c1}.

[0081] η is the sensitivity suppression (truth value) factor as calculated from equation (7).

[0082] δ is the fixed deterioration of the bit error rate arising due to imperfections in the transmitter/receiver (truth value).

b)   QPSK Delay Detection Type Error Rate Characteristic

[0083]

$$BER=Q(a,b) - \frac{1}{2} \times \exp\left[-\frac{a^2+b^2}{2}\right] I_0(ab) \tag{19}$$

$$\begin{cases} a = \sqrt{2}\ \gamma(1 - 1/\sqrt{2)} \\ b = \sqrt{2}\ \gamma(1 + 1/\sqrt{2)} \end{cases}$$

where,

- 22 -

Q: Marcum Q-function

I_0: 0-th modification Bessel function of the first kind

$$\gamma = 1/\{1/(\eta \cdot \delta \cdot E_b/N_0) + 1/(\eta \cdot \delta \cdot Bn \cdot E_b/I_{ACP}) + 1/(\eta \cdot \delta \cdot Bn \cdot E_b/I_3)\} \quad (20)$$

where,

E_b: energy per bit

N_0: noise power density

I_{ACP}: leakage power affecting interfered wireless communication as calculated from interference wave power and reduction factor (IRF) ($I_{ACP} = IRF \times$ power P_3 of interference wave side)

$$Bn \cdot E_b/I_3 - \frac{C}{I_3} \cdot \frac{Bn}{k} \cdot Bn \cdot T \quad (21)$$

[0084] C/I_3 is the power ratio (truth value) of the f_{c1} component expressed by equation (14) and the intermodulation wave component relating to f_{c1} component.

Bn: reception equivalent noise band width of interfered wireless communication

T: time length with respect to symbol period

k: amount of information (bits) per symbol

η: sensitivity suppression (truth value) factor as calculated from equation (7)

[0085] δ is the fixed deterioration of the bit error rate arising due to imperfections of the transmitter/receiver (truth value)

c)   QPSK Absolute Synchronous Detection Error Rate Characteristic

[0086]

$$BER - 1/2 \times erfc \sqrt{\gamma} \quad (22)$$

where,

$$\gamma = 1/\{1/(\eta \cdot \delta \cdot E_b/N_0) + 1/(\eta \cdot \delta \cdot Bn \cdot E_D/I_{ACP}) + 1/(\eta \cdot \delta \cdot Bn \cdot E_b/I_3)\} \quad (23)$$

[0087]   Here,

E_b: energy per bit

N_0: noise power density

- 23 -

I_{ACP}: leakage power affecting interfered wirel ss communication as calculated from interference wave power and reduction factor (IRF) (I_{ACP} = IRF × power P_2 of interference wave side)

$$\text{Bn} \cdot E_b / I_3 = \frac{C}{I_3} \cdot \frac{Bn}{k} \cdot Bn \cdot T \qquad (24)$$

[0088] C/I_3 is the power ratio (truth value) of the f_{a1} component expressed by equation (14) and the intermodulation wave component relating to f_{a1} component.

Bn: reception equivalent noise band width of interfered wireless communication

T: time length with respect to symbol period

k: amount of information (bits) per symbol

η: sensitivity suppression (truth value) factor as calculated from equation (7)

[0089]   δ is the fixed deterioration of the bit error rate arising due to imperfections of the transmitter/receiver (truth value)

d)   QPSK Differential Synchronous Detection Error Rate Characteristic

[0090]   This is found as about double the QPSK absolute synchronous detection error rate characteristic.

$$\text{BER} = \text{erfc} \sqrt{\gamma} \qquad (25)$$

[0099]   Next, the increase in the adjacent leakage power due to the interference wave intermodulation product when the frequency interval of the interference wave and interfered wave is narrow in absolute terms will be explained.

[0100]   As shown by the broken lines of FIG. 5B, when three times the modulation frequency of the modulated wave at the interfering side is broader than the frequency interval of the interference wave and interfered wave, the interference wave component causes the adjacent leakage power to increase due to the third order distortion of the wireless receiver of the

- 24 -

interfered side.

[0101]   If the ratio of the adjacent leakage power increasing by this intermodulation product with the power of the wireless band of the interference wave is designated as IRF_3, it may be expressed as follows:

$$IRF_3 = -10 \times \log[Iin^2] + B \quad (dB) \tag{26}$$

[0102]   Here, B is a constant determined by the frequency spectrum distribution of the frequency f_{c2}, the maximum modulation frequency, the equivalent reception band width (BW) of the frequency f_{c1}, and the frequency interval between the frequency f_{c1} and the frequency f_{c2}.

[0103]   When the frequency spectrum distribution of the interference frequency f_{c2} is constant, if entering equation (2) into equation (4), the component (Y_{fc2}) resulting from third-order distortion of the frequency f_{u2} component is

$$Y_{fc2} = -a_3 \times g(t)^3 \tag{27}$$

[0104]   If entering equation (3) into equation (27), the frequency f_{c2} component is expressed as follows:

$$Y_{fc2} = a_3 \, G \, (3)^{1/2} \cdot \Sigma v_2(k) \cdot \Sigma v_2(l) \cdot \Sigma v_2(m) \cdot \cos(k \cdot 2\pi\Delta f_m \cdot t + \Delta\theta_k) \cdot \cos(l \cdot 2\pi\Delta f_m \cdot t + \Delta\theta 1) \cdot \cos(m \cdot 2\pi\Delta f_m \cdot t + \Delta\theta m)$$

$$(1 \leq k \leq n-2, \; k+1 \leq l \leq n-1, \; l+1 \leq m \leq n) \qquad \times \cos(2\pi f_{c2} t + \theta(t)) \tag{28}$$

Here,

$V_2(k)$: k th modulation signal voltage of baseband of mobile wireless equipment at interfering side

Δf_m: modulation frequency interval of baseband at interfering side

$\Delta\theta_k$: phase of k th modulation frequency of mobile wireless equipment of interfering side

$\Delta\theta_1$: phase of 1st modulation frequency of mobile wireless equipment of interfering side

$\Delta\theta_m$: phase of m-th modulation frequency of mobile wireless equipment of interfering side

$Fm = n \times \Delta f_m$: maximum modulation frequency of mobile wireless of interfering side

f_{c2}: carrier frequency of mobile wireless equipment

- 25 -

of interfering side

$\theta(t)$: phase of carrier frequency of mobile wireless equipment of interfering side

[v]: range of product-sum

[0105]   Expressing equation (28) by the A+B+C type, A+B-C type, A-B+C type, and A-B-C type by combination of the modulation frequencies, expressing the composite frequency of the three modulated waves of the k, l, and m components by L, expressing the composite frequency of the two modulated waves of the l and m components by S, and converting the modulation frequencies to L, S, and m in equation (28), the power with respect to $f_L = L \cdot \Delta f_m$ is expressed by the following:

$$P_{fc2}(f_L) = \hspace{8cm} (29)$$

A+B+C TYPE

$$+3 \times (-a_3 \cdot 3/4 \cdot 2R)^2 \cdot 2/4 \cdot (Pin/Fm)^3 \cdot 1/12 \cdot f_L^2 \hspace{4cm} 1$$

$$Fm \le f_L < 0 \,|\, 0 < f_L \le Fm$$

Here, "|" expresses "or" of the left side condition and right side condition. Namely, the above expression means that $-Fm < f_L < 0$ or $0 < f_L < Fm$ is satisfied.

$$+3 \times (-a_3 \cdot 3/4 \cdot 2R)^2 \cdot 2/4 \cdot (Pin/Fm)^3 \cdot 1/6 \cdot 1/8 \cdot (3Fm - |f_L|)^2 \hspace{2cm} 2$$

$$2Fm \le f_L < Fm \,|\, Fm < f_L \le 2Fm$$

$$+3 \times (-a_3 \cdot 6/8 \cdot 2R)^2 \cdot 2/4 (Pin/Fm)^3 \cdot 1/16 \cdot (f_L - Fm) \cdot (7Fm - 3f_L) \hspace{1cm} -3$$

$$-2Fm \le f_L < -Fm \,|\, Fm < f_L \le 2Fm$$

$$+3 \times (-a_3 \cdot 6/8 \cdot 2R)^2 \cdot 2/4 \cdot (Pin/Fm)^3 \cdot 1/3 \cdot 1/16 \cdot (3Fm - f_L)^2 \hspace{1.5cm} -4$$

$$-3Fm \le f_L < -2Fm \,|\, 2Fm < f_L \le 3Fm$$

$$+3 \times (-a_3 \cdot 6/8 \cdot 2R)^2 \cdot 2/4 \cdot (Pin/Fm)^3 \cdot 1/16 \cdot (3Fm \, f_L)^2 \hspace{2cm} -5$$

$$-3Fm \le f_L < -2Fm \,|\, 2Fm < f_L < 3Fm$$

A+B-C TYPE

$$+3 \times (-a_3 \cdot 6/8 \cdot 2R)^2 \cdot 2/4 \cdot (Pin/Fm)^3 \cdot 1/4 (Fm - |f_L|)^2 \hspace{2.5cm} -6$$

$$-Fm \le f_L < 0 \,|\, 0 < f_L \le Fm$$

$$+3 \times (-a_3 \cdot 6/8 \cdot 2R)^2 \hspace{6cm} -7$$

$$f_L = 0$$

$$+3 \times (-a_3 \cdot 6/8 \cdot 2R)^2 \cdot 2/4 \cdot (Pin/Fm)^3 \cdot 1/4 \cdot (Fm - |f_L|)^2 \hspace{2cm} -8$$

- 26 -

$-Fm < f_L < 0 \mid 0 < f_L \le Fm$

A-B+C TYPE

$+3 \times (-a_3 \cdot 6/8 \cdot 2R)^2 \cdot 2/4 \cdot (Pin/Fm)^3 \cdot (Fm - |f_L|) \cdot |f_L|$ -9

$-Fm \le f_L < 0 \mid 0 < f_L \le Fm$

A-B-C TYPE

$+3 \times (-a_3 \cdot 6/8 \cdot 2R)^2 \cdot 2/4 \cdot (Pin/Fm)^3 \cdot 1/4 \cdot (2Fm - |f_L|)^2$ -10

$-2Fm \le f_L \le -Fm \mid (Fm) \le f_L \le (2Fm)$

$+(-a_3 \cdot 6/8 \cdot 2R)^2 \cdot 2/4 \cdot (Pin/Fm)^3 \cdot 1/4 \cdot f_L^2$ -11

$-Fm < f_L < 0 \mid 0 < f_L < Fm$

[0106]   Applying $a_3/a_1 = 1/(3/2 \cdot IIP3 \cdot R)$ and making the reception pass band of the frequency f_{c1} BW<<Fm, if integrating the power (P_{BW}) in the range of the power $P_{fc2}(f_L)$ to f_{c1} BW/2$\le f_m \le f_{c1}$+BW/2 by equation (29) and dividing the result by the total power of the wireless band of the frequency f_{c2} component to find IRF$_3$, the following is obtained:

$IRF_3 = 10 \times \log(Iin^2) + 10 \times \log \{$ (30)

$+1/4 \times \{f_L^2/Fm^2 + (BW/2)^2/Fm^2\} \cdot (BW/2/Fm)$ ·1

$0 \le f_L \le Fm - BW/2$

$+1/16 \times (BW/2/Fm) \cdot \{(f_L/Fm - 3)^2 + 1/3 \cdot (BW/2)^2/Fm^2\}$ -2

$Fm + BW/2 \le f_L \le 2Fm$

$+3/16 \times (BW/2/Fm) \cdot \{(7 - 3f_L/Fm) \cdot (f_L/Fm - 1) - (BW/2)^2/Fm^2\}$ -3

$Fm + BW/2 \le f_L \le 2Fm - BW/2$

$+1/16 \times (BW/2/Fm) \cdot \{(3 - f_L/Fm)^2 + 1/3 \cdot (BW/2)^2/Fm^2\}$ -4

$2Fm + BW/2 < f_L < 3Fm - BW/2$

$+3/16 \times (BW/2/Fm) \cdot \{(3 - f_L/Fm)^2 + 1/3 \cdot (BW/2)^2/Fm^2\}$ -5

$2Fm + BW/2 \le f_L \le 3Fm - BW/2$

$+1/24 \times [3 - (f_L/Fm - BW/2/Fm)^3 + (f_L/Fm + BW/2/Fm) \cdot \{-2(f_L/Fm + BW/2/Fm)^2 + 9(f_L/Fm + BW/2/Fm) - 9\}]$

$Fm - BW/2 < f_L < Fm + BW/2$ -6

$+3/32 \times [(f_L/Fm - BW/2/Fm) \cdot \{(f_L/Fm - BW/2/Fm)^2 - 5(f_L/Fm - BW/2/Fm) + 7\}$

$2Fm - BW/2 < f_L < 2Fm + BW/2$ $+ (f_L/Fm + BW/2/Fm) \cdot \{1/3(f_L/Fm + BW/2/Fm)^2 - 3 \cdot (f_L/Fm + BW/2/Fm) + 9\}$

                  $-32/3]$ -7

$+1/8 \times [9 - (f_L/Fm - BW/2/Fm) \cdot \{9 - 3(f_L/Fm - BW/2/Fm) + 1/3(f_L/Fm - BW/2/Fm)^2\}]$ -8

$3Fm - BW/2 < f_L < 3Fm$

- 27 -

$$+3/2 \times (BW/2/Fm) \cdot [(1-f_L/Fm)^2 + (BW/2/Fm)^2/3] \qquad -9$$

$$BW/2 < f_L \leq Fm-BW/2$$

$$+3/2 \times [1/3 \cdot (BW/2/Fm) \cdot (3/Fm+(BW/2/Fm)^2 - 3(BW/2/Fm)) + ((BW/2/Fm)-1)f_L^2/Fm/Fm] \qquad -10$$

$$0 \leq f_L < BW/2$$

$$+3/4 \times [-(f_L/Fm-(BW/2/Fm)) + (f_L/Fm-(BW/2/Fm))^2 + 1/3 - (f_L/Fm-BW/2/Fm)^3/3] \qquad -11$$

$$Fm-BW/2 \leq f_L < Fm+BW/2$$

$$+3 \times [f_L/Fm(BW/2/Fm) \cdot (f_L/Fm)^2 (BW/2/Fm) \ 1/3(BW/2/Fm)^3] \qquad -12$$

$$BW/2 < f_L \leq Fm_2-BW/2$$

$$+3/2 \times [(BW/2/Fm)^2 + (f_L/Fm)^2 - 2/3(BW/2/Fm)^3 - 2(BW/2/Fm)(f_L/Fm)^2] \qquad -13$$

$$0 > f_L < BW/2$$

$$+3/2 \times [1/6-1/2(f_L/Fm-BW/2/Fm)^2 + 1/3(f_L/Fm-BW/2/Fm)^3] \qquad -14$$

$$Fm-BW/2 < f_L \leq Fm+BW/2$$

$$+3 \times [1/3(BW/2/Fm)^3 + (f_L/Fm)^2(BW/2/Fm)] \qquad -15$$

$$0 < f_L < Fm-BW/2$$

$$+3/4 \times [(2-f_L/Fm)^2(BW/2/Fm) + 1/3(BW/2/Fm)^3] \qquad -16$$

$$Fm+BW/2 < f_L \leq 2Fm-BW/2$$

$$(3/0 \times [2 \ (f_L/Fm \ BW/2/Fm)^3/3 + (f_L/Fm+BW/2/Fm)$$

$$Fm-BW/2 < f_L < Fm+BW/2 \qquad \cdot (4-2(f_L/Fm+BW/2/Fm) + (f_L/Fm+BW/2/Fm)^2/3)] \quad 17$$

$$+3/4 \times [4/3 - (f_L/Fm \ BW/2/Fm) \cdot (2-(f_L/Fm-BW/2/Fm) + 1/6(f_L/Fm-BW/2/Fm)^2)] \qquad -18$$

$$2Fm-BW/2 < f_L \leq 2Fm$$

}

[0107]   Here, the frequency f_{c1} and f_{c2} are normalized by the input third-order intercept point IIP3 to obtain:

$$a_3/a_1 = 1/(3/2 \cdot R \cdot IIP3)$$

$$I_{11} = V_1^2/2/R/(IIP3)$$

$$I_{12} = 1/2 \cdot V_2^2/2/R/(IIP3)$$

[0108]   The dB value of equations (30)-1 to 18 is the constant B of equation (26).

[0109]   The error rate characteristic is found by making the IRF_3 obtained by converting the IRF_3 (dB value) expressed by equation (30) to a truth value less than the leakage power value of equations (18), (20), and (23).

$$I_{ACP} = (IRF \ IRF_3) \times Power \ of \ Interfering \ Side \ P_2$$

Here, BW is the frequency band width of the interference signal, Fm is half of the maximum modulated

- 28 -

wave frequency band width of the interference signal, and
"|" means "or".

[0110]   The following action is obtained by the
interference measurement and evaluation system according
to the present invention explained in brief above:

[0111]   It is possible to express the correspondence
with the BER characteristic from the intercept point
input level (IIP), reception thermal noise, and
interference leakage power from an adjacent channel as a
nonlinear characteristic of the interfered reception
system using equations (7) and (14) expressing the signal
of the desired wave input for reception of a modulated
wave and signal of the interference wave by a discrete or
continuous spectrum, equations (16) to (18) expressing
the delay detection type simplified error rate
characteristic, equations (19) to (21) expressing the
QPSK delay detection type error rate characteristic,
equations (22) to (25) expressing the QPSK absolute
synchronous detection error rate characteristic, or
double the bit error rate characteristic of equations
(22) to (25) for the error rate characteristic of the
QPSK differential synchronous detection error rate
characteristic. Therefore, it is possible to enable
estimation of the IIP3 of the reception as a whole and to
more precisely and flexibly provide line qualities under
nonlinear interference from the estimated IIP3.

[0112]   FIG. 6 is a graph of an example of the bit
error rate characteristic as an example of a line quality
characteristic under nonlinear interference measured
using the interference measurement and evaluation system
shown in FIG. 1 as a test system. In FIG. 6, the curve A
is the bit error rate characteristic when there is no
interference, and the curves B to E show the bit error
rate characteristic under nonlinear interference when
gradually increasing and measuring the interference wave
power. The points 61 to 64 are points of the received
signal level versus bit error rate characteristic of the

- 29 -

modulated wave signal when converting the ratio D/U of
the power D of th desired wave (interfered side) and the
power U of the interference wave to a constant one. The
curve F shows the bit error rate characteristic under
nonlinear interference when making constant the D/U
estimated by connecting the points 61 to 64.

[0113]   To change the level of the received signal
while making D/U constant, either only the transmitting
side variable attenuator 13 is controlled or both the
transmitting side variable attenuator 13 and interference
side variable attenuator 16 are controlled. This control
may be performed by the interference characteristic
estimating means 20 or may be performed by other means.

[0114]   In this embodiment, the points 61 and 62 are
points where the bit error rate satisfies 1.3×10^{-1} as an
example. The bit error rate employed may be any error
rate so long as it is in a region where the nonlinear
interference is dominant. Note that the gradations
1.00E+00, 1.00E-01, 1.00E-2,... of the ordinate showing
the bit error rate mean 1×10^{0}, 1×10^{-1}, 1×10^{-2}... The lower
in the figure, the lower the error rate. Further, the
unit of the level of the normalized received signal of
the abscissa is the decibel (dB). The further to the left
in the figure, the lower the received level.

[0115]   Here, the intercept point input level IIP3 of
the receiving side as a whole in interfered wireless
communication can be estimated from the following
equation (32) from the normalized received signal level
I_{i1} at 1.3×10^{-2} as an example of the bit error rate at the
received level region near the point 61 where the
nonlinear interference is dominant and the measured value
P_{r1} at the bit error rate 1.3×10^{-2}.

$$IIP3 = P_{r1}/I_{i1} \qquad\qquad (32)$$

[0116]   However, the following conditions must be
satisfied:

    1) The bit error rate 1.3×10^{-2} near the line

- 30 -

connecting the points 61 and 62 be a region where there
is no effect from the received noise power, there is a
level difference, and nonlinear interference is dominant.

2) The bit error rate 1.3×10^{-2} near the line
connecting the points 61 and 62 be a region where there
is no effect of the leakage power from the interference
wave, the error rate of the curve B is sufficiently low,
and nonlinear interference is dominant.

Second Embodiment

[0117]   FIG. 7 is a block diagram of the configuration
of an interference measurement and evaluation system
according to a second embodiment of the present
invention. In the figure, the difference from FIG. 1 is
that the receiving side variable attenuator 21 is
connected between the hybrid composition circuit 17 and
the interfered digital wireless equipment 18 in the
receiving means.

[0118]   In this embodiment, by adjusting the receiving
side variable attenuator 21, the received level of the
interfered digital wireless equipment 18 is controlled
while making constant the ratio D/U of the modulated wave
signal output input to the interfered digital wireless
equipment 18 and the modulated carrier signal output from
the interfering digital wireless equipment 15.

[0119]   FIG. 8 is a graph of an example of the bit
error rate characteristic under nonlinear interference
measured using the test system shown in FIG. 7. In the
figure, the curve G shows the bit error rate
characteristic when there is no interference, while the
curve H shows the bit error rate characteristic under
nonlinear interference. In this example, the points 81
and 82 on the curve H are points where the bit error rate
is 1×10^{-2} as an example.

[0120]   Here, the intercept point input level TTP3 of
the receiving side as a whole in interfered wireless
communication can be estimated from the following

- 31 -

equation (33) from the normalized received signal level I_{i1} at a bit error rat of 10^{-2} as an xample at the received level region where the nonlinear interference is dominant and the measured value P_{r1} at the bit error rate 10^{-2}.

$$IIP3-P_{r1}/I_{i1} \qquad\qquad (33)$$

[0121]   However, the following conditions must be satisfied:

    1) The bit error rate 10^{-2} near the line connecting the points 81 and 82 be a region where there is no effect from the received noise power, there is a level difference, and nonlinear interference is dominant.

    2) The bit error rate 10^{-2} near the line connecting the points 81 and 82 be a region where there is no effect of the leakage power from the interference wave, the error rate of the curve G is sufficiently low, and nonlinear interference is dominant.

    Third Embodiment

[0122]   In the present embodiment, the variable attenuator 13 and interfering modulated signal generator 14 shown in FIG. 1 or FIG. 7 are adjusted or the receiving side variable attenuator 21 is adjusted to lower the input level of the receiving means while maintaining the D/U constant so as to estimate the reception thermal noise characteristic.

[0123]   FIG. 9 and FIG. 10 are views of the thermal noise characteristic under nonlinear interference measured using the interference wave power as a parameter. FIG. 9 and FIG. 10 are graphs substantially the same as FIG. 6 and FIG. 8. The difference is that in FIG. 9 and FIG. 10, the received level is lowered and the receiver thermal noise is estimated from the received level of the region where thermal noise is dominant where an increase in the bit error rate due to the receiver thermal noise would become a problem.

[0124]   Explaining this using FIG. 10 as an example, the measured reception thermal noise (Pn (unit: dB_m)) is

- 32 -

estimated as follows based on the normalized received
level I_{10} (dB) (not shown) determined from the received
noise power, the level of the normalized received level
I_{11} (dB) determined under nonlinear interference at the
point 82 where the line of the bit error rate 10^{-2} of an
example of the bit error rate at the received level
region where the nonlinear interference is dominant
intersects the curve H in the region of a low receiving
level where the thermal noise would interfere with the
inherent received signal, and the level difference
showing the same bit error rate tested at a line quality
test system:

$$P_n - (I_{11} + IIP3) - \Delta - D \tag{34}$$

[0125]   Here, Δ is the difference ($\Delta = P_B - P_A$) between the
measured received level P_B giving the bit error rate 10^{-2}
and the measured received level P_A giving the bit error
rate 10^{-2} at the curve G when there is no interference,
while D is the fixed deterioration showing the difference
between the received level and theoretical value when the
bit error rate characteristic 10^{-2} at the curve G when
there is no interference.

    Fourth Embodiment

[0126]   FIG. 11 is a block diagram of the configuration
of an interference measurement and evaluation system
according to a third embodiment of the present invention.
In the figure, the difference from FIG. 7 is that a
frequency conversion circuit 22 for changing the
frequency of the interference wave is connected between
the interfering digital wireless equipment 15 in the
nonlinear interfering means and hybrid composition
circuit 17. This frequency conversion circuit 22 is
comprised by a mixer circuit, a frequency shift local
oscillator, a splice signal removing band pass filter,
etc.

[0127]   The frequency conversion circuit 22 can change
the generated frequency of the frequency shift local

- 33 -

oscillator.

[0128]   In the present embodiment, the carrier frequency of the interference wave is changed so as to estimate the reception equivalent band limitation of the receiving side as a whole from the receiving side input level versus reception error rate characteristic of the modulated wave signal.

[0129]   FIG. 12 is a graph of an example of the bit error rate characteristic under nonlinear interference measured using the interference measurement and evaluation system shown in FIG. 11. In the figure, curve I shows the bit error rate characteristic when there is no interference, curve J shows the bit error rate characteristic under nonlinear interference when the carrier frequency of the interfering digital wireless equipment does not cause attenuation at the initial band pass characteristic of the interfered digital wireless equipment, and the curve L shows the bit error rate characteristic under nonlinear interference when the carrier frequency of the interfering digital wireless equipment causes more attenuation at the initial band pass characteristic of the interfered digital wireless equipment.

[0130]   The IIP3 of the receiving side of the interfered wireless communication device is found by the following equation (35) from the received level $I_{i1}(1)$ at the bit error rate 10^{-2} as an example of the bit error rate near the received level region where nonlinear interference is dominant when the carrier frequency of the interfering digital wireless equipment does not cause attenuation at the graph J showing the initial band pass characteristic of the interfered digital wireless equipment and the measured value P_{r1} of the power at the bit error rate 10^{-2}.

$$IIP3 = P_{r1}/I_{i1} \tag{35}$$

[0131]   However, the following conditions must be satisfied:

- 34 -

1) The receiving region of a bit error rate of 10^{-2} be a region where there is no effect from the received noise power, there is a level difference, and nonlinear interference is dominant.

2) The receiving region of a bit error rate of 10^{-2} be a region where there is no effect of the leakage power from the interference wave, the error rate of the curve J is sufficiently low, and nonlinear interference is dominant.

[0132]   Regarding the attenuation with respect to the carrier frequency of any interfering digital wireless equipment, if the frequency interval between the center frequency of the interfered digital wireless equipment and center frequency of the interfering digital wireless equipment is made $\Delta f(2)$ for the curve K and is made $\Delta f(3)$ for the curve L, the equivalent attenuation at the initial band pass characteristic may be found from the following equations (36) and (37) from the normalized interfering levels $I_{11}(2)$ and $I_{11}(3)$ at the bit error rate 10^{-2}:

$$L(2)=I_{11}(1)-I_{12}(2) \tag{36}$$
$$L(3)=I_{11}(1)-I_{12}(3) \tag{37}$$

Fifth Embodiment

[0133]   In this embodiment, the interference measurement and evaluation system shown in FIG. 1 is used to estimate the reception equivalent leakage power which the interference wave of the receiving side as a whole has on the receiving side or interference reduction factor from the receiving side input level versus receiving error rate characteristic of the modulated carrier signal.

[0134]   FIG. 13 is a graph expressing the equation of the bit error rate characteristic under nonlinear interference measured using the interference measurement and evaluation system shown in FIG. 1 by the D/U (truth value) and showing an example of the bit error rate

- 35 -

characteristic under nonlinear interference. A curve
substantially the same as FIG. 10 is drawn.

[0135]   In FIG. 13, the curve G shows the bit error
rate characteristic when there is no interference, while
the curve H shows the bit error rate characteristic when
the D/U under nonlinear interference is constant. The
point 111 on the curve H is the point where the bit error
rate characteristic shows the best value. The normalized
received signal level is $I_{11}(4)$.

[0136]   If setting

$$(D/U)=I_{11}/I_{12} \tag{38}$$

$$\eta=20\times\log|1-I_{111}-2\cdot I_{11}/(D/U)| \tag{39}$$

[0137]   Further,

$$C/I3-20\times\log|\{1-I_{11}-2\cdot I_{11}/(D/U)\}/\{I_{11}/(D/U)\}|-3dB \tag{40}$$

[0138]   As an example, as a delay detection type
simplified error rate characteristic,

$$BER=1/2\times\exp(-\rho/2) \tag{41}$$

$$Ln(2\times BER)=-\rho/2 \tag{42}$$

[0139]   Here, if the signal-to-noise power ratio is ρ,
ρ become as in the following equation:

$$\rho=1/\{1/(\eta\cdot\delta\cdot C/P_N)+1/(\eta\cdot\delta\cdot C/I_{ACP})+1/(\eta\cdot\delta\cdot C/I_3)\} \tag{43}$$

[0140]   Here, if the leakage power IACP is expressed by
the ratio (IRF) between the leakage power of the
interference wave and the initial band pass level of the
adjacent interfered digital wireless equipment,

$$\rho=1/\{1/(\eta\cdot\delta\cdot C/P_N)+1/(\eta\cdot\delta\cdot C/IF3/IRF/I_{12})+1/(\eta\cdot\delta\cdot C/I_3)\} \tag{44}$$

[0141]   If the normalized interfered wave level at the
best value of the bit error rate when making D/U constant
is I_{11}, using equation (38):

$$\rho=1/[1/(\eta\cdot\delta\cdot C/P_N)+1/\{\eta\cdot(\delta\cdot D/U)/IRF\}+1/\{\eta\cdot\delta\cdot C/I_3\}] \tag{45}$$

[0142]   From equation (42) and equation (45),

$$-1/2/Ln(2\times BER)=1/(\eta\cdot\delta\cdot C/P_N)+1/\{\eta\cdot\delta\cdot(D/U)/IRF\}+1/\{\eta\cdot\delta\cdot C/I_3\}] \tag{46}$$

[0143]   From equation (46),

$$IRF=\{\eta\cdot\delta\cdot(D/U)\times[-1/2/Ln(2\times BER)-1/(\eta\cdot\delta\cdot C/P_N)-1/\{\eta\cdot\delta\cdot C/I_3\}]\} \tag{47}$$

[0144]   The leakage power ratio IRF is found using the

- 36 -

above equations (38), (40), and (47) from the received
signal level I_{i1} of the normalized interfered signal at
the best value of the bit error rate when making D/U
constant and the noise power (P_N) of the interfered
digital wireless equipment..

[0145]   Here, Ln( ) indicates the natural log (bottom
"e").

[0146]   However, the point 111 showing the best bit
error rate is the region where there is no effect from
the nonlinear interference and received noise power on
the curve H of the constant D/U ratio, there is a level
difference, and the leakage power is dominant.

     Sixth Embodiment

[0147]   In this embodiment, an error rate
characteristic test system for measuring the wireless
communication line error rate under interference of the
fifth embodiment is used to estimate the receiving side
reception equivalent leakage power or interference
reduction factor for the offset frequency of the
modulated wave signal and interference signal from the
receiving side input level versus reception error rate
characteristic of the modulated wave signal with respect
to the offset frequency of the modulated wave signal
changed in the carrier frequency of the interference wave
and the interference wave.

[0148]   FIG. 14 is a graph expressing the equation of
the bit error rate characteristic under nonlinear
interference measured using the test system shown in FIG.
7 by the D/U (truth value) and showing an example of the
bit error rate characteristic under nonlinear
interference corresponding to the frequency difference of
the interference signal and interfered signal (offset
frequency Δf_1).

[0149]   In FIG. 14, the curve M shows the bit error
rate characteristic when there is no interference, while
the curve N shows the bit error rate characteristic when
the D/U under nonlinear interference is constant. The

- 37 -

point 111 on the curve B is the point where the bit error
rate characteristic shows the best value. The normalized
received signal level is $I_{11}(4)$.

[0150]   The normalized interfered wave received signal
level of the best value of the bit error rate at the time
of making the D/U constant for the offset frequency Δf_1
of the interference wave is $I_{11}(\Delta f_1)$ and the noise power
of the interfered digital wireless equipment is (Γ_N), so
IRF (Δf_1) is found from equation (47) using equations
(38), (39) and (40). In this case, the effect of the
leakage power is relatively small.

[0151]   Further, the curve O in FIG. 14 shows the bit
error rate characteristic under nonlinear interference
when the offset frequency of the interference wave is Δf_2
smaller than Δf_1. The point 142 is the point where the
bit error rate characteristic in that case is the best
value. The normalized received signal level is $I_{11}(2)$.
The leakage power ratio IRF (Δf_2) becomes larger than IRF
(Δf_1).

[0152]   In this case as well, the leakage power ratio
IRF (Δf_2) is found in the same way as above. IRF (Δf_2)
becomes larger than IRF (Δf_1).

[0153]   Further, the curve P in FIG. 14 shows the bit
error rate characteristic under nonlinear interference at
the offset frequency Δf_3 smaller than Δf_2 of the
interference wave. The point 143 is the point of the best
value of the bit error rate characteristic. The
normalized received signal level is $I_{11}(3)$.

[0154]   In this case as well, the leakage power ratio
IRF (Δf_3) is found in the same way as above. IRF (Δf_3)
becomes larger than IRF (Δf_2).

[0155]   However, the points 141, 142, and 143 showing
the best bit error rate preferably are regions where the
leakage power of a level difference of no effect from the

- 38 -

nonlinear interference and received noise power on the curves N, O, and P where the D/U ratio is made constant is dominant.

Seventh Embodiment

[0156]   In the present embodiment, in the same way as in the sixth embodiment, the reception equivalent leakage power of the receiving side is estimated for the offset frequency of the modulated wave signal and interference signal, but when the received signal level measurement is discrete, IIP3 and P_n are given, but the receiving side input level versus received error rate characteristic for the D/U is only obtained discretely, but in this case as well, it is possible to approximate the input level at the best value of the receiving side input level versus reception error rate characteristic and estimate the reception equivalent leakage power or the interference reduction factor.

[0157]   From equation (47),

$$-1/2/\text{Ln}(2\times\text{BER})=1/(\eta\cdot\delta\cdot C/P_N)+1/\{\eta\cdot\delta\cdot(D/U)/\text{TRF}\}+1/\{\eta\cdot\delta\cdot C/I_3\} \quad (48)$$

[0158]   Here,

$$(D/U)=I_{i1}/I_{i2} \quad (49)$$

$$\eta=[1\cdot I_{Ii1} \ 2\cdot I_{i1}/(D/U)]^2 \quad (50)$$

$$C/I3=1/2\times[1-I_{i1}-2\cdot I_{i1}{}^3/(D/U)^2]^2 \quad (51)$$

[0159]   Tt designating the receiving side input level when measuring the bit error rate characteristic $I_{i1}(1)$, $T_{i1}(2),\ldots I_{i1}(n)$ and the bit error rate at those times ber(1), ber(1),... ber(n) and using polynomial interpolation as an example of approximation,

$$\text{BER}(r)=\text{ber}(1)\times L_1(r)+\text{ber}(1)\times L_2(r)+\cdots\text{ber}(1)\times L_n(r) \quad (52)$$

[0160]   Here,

$$L_i(r)=\frac{(r-r_1)\cdot(r-r_{i-1})(r-r_{i+1})\cdots(r-r_n)}{(r_i-r_1)\cdot(r_i\cdot r_{i-1})(r_i \ r_{i+1})\cdots(r_i-r_n)}$$

$$r_k=I_{i1}(k)$$

[0161]   If differentiating the bit error rate by "γ"

- 39 -

when D/U is constant, the minimum value is

$$0 - \frac{d}{dr} d[\text{ber}(1) \times L_1(r) + \text{ber}(1) \times L_2(r) + \cdots \text{ber}(1) \times L_n(r)]$$

[0162]   From the above, "γ" is found, BER(r) is found from equation (52), and IRF is found by entering equation (50) and equation (51) into equation (48).

[0163]   The present embodiment can also be realized by the interference evaluation system shown in FIG. 11. In FIG. 11, the interference evaluating means 20 collects information from the variable attenuators 13, 16, and 21 and the frequency conversion circuit 22, enters the bit error rate of the error rate measuring device 19 as data, and uses the algorithm shown in the present embodiment to specify the input level at the best value for the discrete offset frequency and estimate the reception equivalent leakage power or interference reduction factor.

        Eighth Embodiment

[0164]   In the present embodiment, it is made possible to estimate the line quality characteristics of a receiving means for the level or offset frequency of the interference signal of any signal using the nonlinear interference theoretical value or theoretical curve.

[0165]   That is, a means is provided for enabling estimation of the nonlinear interference characteristic from the region where the nonlinear interference is dominant for any offset frequency, estimation of the reception thermal noise from the IIP3 as the reception performance and region where the reception thermal noise is dominant, estimation of the interference reduction factor of the interference signal from the reception thermal noise as the reception performance and the region where the adjacent power is dominant, and estimation of the bit error rate under nonlinear interference for any offset frequency signal and input power level of the interference signal from the known interference reduction

- 40 -

factor using equations (7) and (14) and using equations (16) to (18) expressing the delay detection type simplified error rate, equations (19) and (20) expressing the QPSK delay detection type error rate, equations (22) and (23) expressing the QPSK absolute synchronous detection error rate, or double the bit error rate characteristic of equations (22) and (23) for the bit error rate characteristic of the QPSK differential synchronous detection error rate characteristic.

Ninth Embodiment

[0166]   In the present embodiment, even if the measured values of the receiving side input level and reception line quality characteristic linked with the nonlinear interference theoretical curve are discrete, it is possible to estimate the nonlinear interference characteristic for any offset frequency, automatically estimate the adjacent leakage power etc., and estimate the line quality characteristic.

[0167]   If the receiving side input level when measuring the bit error rate characteristic is C_1, C_2,... C_n and the thermal noise of the reception system is Pn, the bit error rates at that time are ber_1, ber_2,... ber_n, so using polynomial interpolation as an example of approximation:

$$BER(r)=ber_1 \times L_1(r)+ber_2 \times L_2(r)+\cdots ber_n \times L_n(r) \qquad (53)$$

[0168]   Here,

$$L_i(r) = \frac{(r - r_1)\cdot(r - r_{i-1})(r - r_{i+1})\cdot(r - r_n)}{(r_i - r_1)\cdot(r_i - r_{i-1})(r_i - r_{i+1})\cdot(r_i - r_n)}$$

$$r_i = C_i/Pn$$

[0169]   In general, using equation (17) and equation (18),

$$p-A^2/2/50/\sigma^2 \qquad (54)$$

σ^2: noise power

[0170]   If the received power of the frequency f_{c1} is C, the sensitivity suppression factor is η, and δ is the

- 41 -

fixed parameter, ρ becomes the following equation:

$$\rho = 1/\{1/(\eta \cdot \delta \cdot C/P_N) + 1/(\eta \cdot \delta \cdot C/I_{ACP}) + 1/(\eta \cdot \delta \cdot C/I3)\} \qquad (55)$$

10th Embodiment

[0171]   In this embodiment, the nonlinear interference characteristic of the receiving side as a whole is estimated based on the receiving side input level versus reception line quality characteristic of the modulated carrier signal and the received levels at the region where the adjacent power is dominant and the region where the received thermal noise is dominant.

[0172]   FIG. 15 is a graph of the bit error rate characteristic under nonlinear interference in a 10th embodiment. In the figure, the curve Q shows the bit error rate characteristic when there is no interference, while the curve R shows the bit error rate characteristic when making the interference power larger. As shown in the figure, in this case, data is not obtained in the region where the interference power is dominant. In this embodiment, the nonlinear interference characteristic of this unknown region is estimated by the following technique.

[0173]   From equation (56),

$$-1/2/Ln(2 \times BER) = 1/(\eta \cdot \delta \cdot C/P_N) + 1/(\eta \cdot \delta \cdot (D/U)/IRF) + 1/(\eta \cdot \delta \cdot C/I_3) \qquad (56)$$

[0174]   Here,

$$(D/U) = T_{11}/T_{12} \qquad (57)$$

$$\eta = [1 - I_{11} - 2 \cdot I_{11}/(D/U)]^2 \qquad (58)$$

$$C/I_3 = 1/2 \times [1 - T_{11} - 2 \cdot T_{11}^2/(D/U)^2]^2 \qquad (59)$$

[0175]   When D/U is constant and C/PN and D/U/IRF are known, equation(56) is found from equation (60)

$$-1/2/Ln(2 \times BER) = 1/\eta \times \delta_x (C/P_N) + 1/(\eta \times \delta_x (D/U)/IRF) + 1/(\eta \times \delta_x \times (C/I_3)) \qquad (60)$$

From the equation (60), equation (58), and equation (59), the reception signal level I_{11} is determined.

[0176]   If considering the fact that this is not a nonlinear region, η is set as "1" and equation (60) becomes as follows using equation (59):

$$C/I_3 = \cfrac{1}{-\cfrac{1}{2 \cdot Ln(2 \times BER)} - \cfrac{1}{(\delta \cdot C/P_N)} - \cfrac{1}{(\delta \cdot D/U) \cdot IRF}} \qquad (61)$$

$$\frac{1}{2} \cdot [1 - I_{11} - 2 \cdot I i_1{}^2 / (b/v)^2]^2 = \cfrac{1}{-\cfrac{1}{2 \cdot Ln(2 \times BER)} - \cfrac{1}{(\delta \cdot C/P_N)} - \cfrac{1}{(\delta \cdot D/U) \cdot IRF}} \qquad (62)$$

$$[1 - I_{11} - 2 \cdot I_{11}{}^2 / (D/U)^2] = \cfrac{2}{\sqrt{-\cfrac{1}{2 \cdot Ln(2 \times BER)} - \cfrac{1}{(\delta \cdot C/P_N)} - \cfrac{1}{(\delta \cdot D/U) \cdot IRF}}} \qquad (63)$$

$$I_{11} = \cfrac{-1 + \sqrt{1 + 8/(D/U)^2 \times [1 - \sqrt{\cfrac{2}{-\cfrac{1}{2 \cdot Ln(2 \times BER)} - \cfrac{1}{(\delta \cdot C/P_N)} - \cfrac{1}{(\delta \cdot D/U) \cdot IRF}}}]}}{\{4/(D/U)^2\}} \qquad (64)$$

[0177]   If making the measured value Pr, IIP becomes

$$IIP3 = P_r/Ti1 \qquad (65)$$

[0178]   Summarizing the effects of the invention, as clear from the above explanation, according to the present invention, since an interference measurement and evaluation system using a nonlinear interference theoretical curve linked with a received line quality characteristic so as to estimate the reception characteristics under nonlinear interference, estimate the reception thermal noise characteristic, estimate the ratio between the third-order distortion coefficient a_3 and first-order distortion characteristic due to nonlinear interference or third-order intermodulation (IIP3), estimate the reception pass band characteristic, and estimate the leakage power from an adjacent channel is provided, it becomes possible to take measures against

- 43 -

d terioration of the line quality due to nonlinear interference.

[0179]   While the invention has been described with reference to specific embodiments chosen for purpose of illustration, it should be apparent that numerous modifications could be made thereto by those skilled in the art without departing from the basic concept and scope of the invention.